



Geographia Polonica
2015, Volume 88, Issue 2, pp. 139-145
<http://dx.doi.org/10.7163/GPol.0020>



INSTITUTE OF GEOGRAPHY AND SPATIAL ORGANIZATION
POLISH ACADEMY OF SCIENCES
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THE DIVERSITY OF SOILS OF THE UPPER FOREST LINE, TRANSITION, AND MOUNTAIN PINE ZONES IN THE BABIA GÓRA MASSIF

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Abstract

The upper forest line transition zone up to the mountain pine zone on the southern slopes of Babia Góra, has diversified phytosociology and soils. The development and diversity of the upper forest soils are affected by morphogenetic processes, physiographic conditions, vegetation, and anthropogenic factors which in the past included sheep grazing. An analysis conducted on the morphological and chemical soil properties in the transects covering the upper forest line, transition, and mountain pine zone on the southern slopes of Babia Góra revealed considerable diversification characterising these soils within the individual altitude zones. A substantial changeability in the contents of the analysed components in the investigated soils is characteristic for mountain soils developed in the areas with great intensity of slope phenomena and processes.

Key words

Babia Góra Mt • soils • upper forest line

Introduction

On Babia Góra, like in the other parts of the Carpathians, the kind of bedrock, geomorphological processes, vegetation, climate or physiographic conditions are among the factors affecting development of soil cover (Kotarba 1990; Skiba 1995, 2006; Miechówka

et al. 2004). There are also the anthropogenic factors to be considered, mainly associated with sheep farming (Zaleski 1996), which on this terrain was most intensive in the 18th and 19th centuries (Czajka et al. 2010). At that time, the highest situated tree stands were cut down, which led to the lowering of the upper forest line. Pasturing has since

been discontinued on the Babia Góra slopes, and the gradual process of vegetation cover reconstruction has been taking place due to succession (Czajka et al. 2010). Because of very strong dependencies between the vegetation and soil of a given habitat (Skiba 1998; Miechówka et al. 2004, 2006), the process may influence the development of soil cover and diversification of properties within a soil profile of this region.

The investigations attempted to determine the effect of habitat changes on soil properties in the transition zone between the upper forest line and mountain pine zone on the southern slopes of Babia Góra.

Materials and methods

Five research polygons – 1, 2, 3, 4, and 5 were appointed to determine the soil properties of the upper forest (Fig.1). On each of the polygons, three soil pits were made that were located as follows:

- in plant communities of the upper mountain zone (PRG), where the acidophilus West-Carpathian upper mountain spruce (*Plagiothecio-Piceetum*) occurred,
- in the transition zone (SP) between the upper forest line and mountain pine shrubs,
- in the mountain pine zone under mountain pine (*Pinus mugo*) shrubs, under grassy vegetation and herb communities (PK).

Fifteen soil profiles were made, whose localisation was determined using the GPS technique (Tab.1).

During field work, soil morphological properties were determined and samples for laboratory analyses were taken from each of the identified genetic horizons. The following assessments were made in the samples:

- pH in H₂O and 1 mol · dm⁻³ KCl solution by the electrometric method using pH-meter with a universal electrode calibrated in buffer solutions (Tan 1996),
- hydrolytic acidity (Hh) by Kappen's method following extraction with 1 mol · dm⁻³ CH₃COONa (Lityński et al. 1976),
- exchangeable acidity using Sokołow's method, after extraction with 1 mol · dm⁻³ KCl,

in whose extract exchangeable H⁺ was determined after precipitation of Al³⁺ ions with 2.3 mol · dm⁻³ NaF (Lityński et al. 1976),

- base exchange capacity (S) through determining individual cations (Ca⁺², Mg⁺², K⁺, Na⁺) after their extraction with 1 mol · dm⁻³ CH₃COONH₄ (Lityński et al. 1976) using the ICP-AES technique,
- organic carbon content (C org.), total nitrogen (N og.) and total sulphur (S og.) by means of the thermal method using an LECO C-NS 2000 analyser,
- content of available phosphorus (P) and potassium (K) extracted using the Enger-Riehm method (Lityński et al. 1976) by means of the ICP-AES method.

On the basis of the obtained results, the following were computed:

- potential cation exchange capacity (PCEC):
PCEC = Hh + S
- sorption complex saturation with base cations (V):

$$V = \frac{S}{PCEC} \cdot 100$$

Results and discussion

Soils of the southern part of the Babia Góra massif developed from the Magura sandstones on slopes having an average gradient of 25°. Despite such a considerable slope gradient, all analysed soils were characterised by well-developed, mostly organic-accumulative horizons. These horizons formed as a result of the accumulation of organic matter originating from the decomposed vegetation which covered the horizons. An apparent zonality of soil location occurs in the Babia Góra area (Adamczyk & Baran 1963; Adamczyk 1983; Miechówka et al. 2004, 2006), which causes a diversity within the soil profile, especially as far as the thickness of accumulative horizons is concerned. Accumulative horizons having the greatest thickness characterised the soils covering the upper mountain zone, under upper mountain forest, where the average thickness was 10.4 cm. In soils of the transition zone between the upper mountain

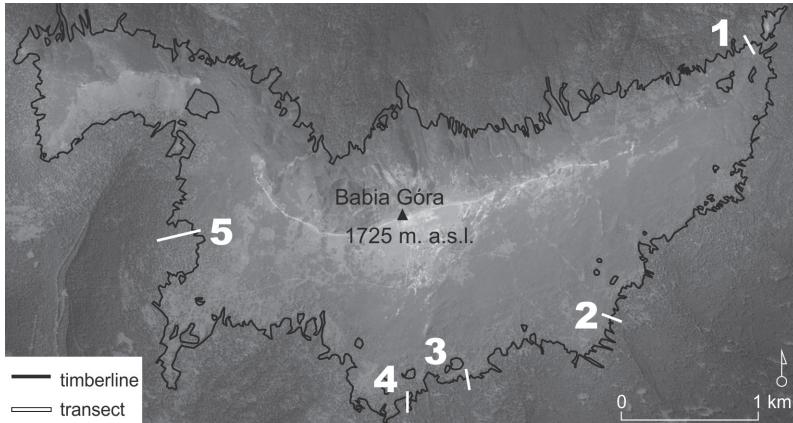


Figure 1. Location of research transects

Table 1. Typological classification and localisation of the analysed soils

Profile	Soil type and sub-type (Marcinek & Komisarek 2011)	Localisation and altitude	Vegetation (Matuszkiewicz 2005)
1PRG	Cambic Skeletic Leptosols	49°35'00,8"N, 19°33'41,5"E 1367 m n.p.m.	acidophilous West Carpathian mountain spruce (<i>Plagiothecio-Piceetum</i>)
1SP	Cambic Skeletic Leptosols	49°35'00,4"N, 19°33'41,4"E 1370 m n.p.m.	transition zone between closed forest and mountain pine shrubs
1PK	Cambic Skeletic Leptosols	49°35'00,1"N, 19°33'42,5"E 1380 m n.p.m.	mountain pine shrubs (<i>Pinusmugo</i>)
2PRG	Dystric Skeletic Leptosols	49°34'01,8"N, 19°32'55,9"E 1335 m n.p.m.	high mountain spruce (<i>Plagiothecio-Piceetum</i>)
2SP	Cambic Skeletic Leptosols	49°34'02,0"N, 19°32'55,6"E 1344 m n.p.m.	transition zone between closed forest and mountain pine shrubs
2PK	Cambic Skeletic Leptosols	49°34'02,6"N, 19°32'55,9"E 1365 m n.p.m.	mountain pine shrubs (<i>Pinusmugo</i>)
3PRG	Cambic Skeletic Leptosols	49°33'48,1"N, 19°32'06,8"E 1384 mn.p.m.	high mountain spruce
3SP	Dystric Skeletic Leptosols	49°33'49,0"N, 19°32'06,0" E 1393 m n.p.m.	transition zone between closed forest and mountain pine shrubs
3PK	Hyper Skeletic Leptosols	49°33'48,3"N, 19°32'06,4"E 1411 m n.p.m.	mountain pine shrubs (<i>Pinusmugo</i>)
4PRG	Dystric Skeletic Leptosols	49°33'40,9"N, 19°31'49,8"E 1345 m n.p.m.	high mountain spruce
4SP	Cambic Skeletic Leptosols	49°33'42,2"N, 19°31'48,8"E 1366 m n.p.m.	transition zone between closed forest and mountain pine shrubs
4PK	Cambic Skeletic Leptosols	49°33'45,5"N, 19°31'48,4"E 1391 m n.p.m.	mountain pine shrubs (<i>Pinusmugo</i>)
5PRG	Dystric Skeletic Leptosols	49°34'21,1"N, 19°30'27,7"E 1420 m n.p.m.	high mountain spruce
5SP	Cambic Skeletic Leptosols	49°34'20,6"N, 19°30'29,8"E 1440 m n.p.m.	transition zone between closed forest and mountain pine shrubs
5PK	Skeletic Leptosol	49°34'21,1"N, 19°30'27,7"E 1448 m n.p.m.	mountain pine shrubs (<i>Pinusmugo</i>)

Table 2. Chemical properties of analysed soils (median value/variation coefficient)

Altitude zone	C org.	Nog.	Sog.	K	P	pH		S	Hh	PWK	V
	g · kg ⁻¹			mg · kg ⁻¹		H ₂ O	KCl	mmol(+) · kg ⁻¹			%
Accumulative horizons											
PRG	283.6/0.7	14.9/0.6	1.43/0.6	216.4/0.9	145.2/0.7	3.6/0.1	2.76/0.1	28.4/1.2	735.0/0.6	887.3/0.6	3.6/1.0
SP	121.6/0.9	6.1/0.8	0.8/0.7	85.6/1.0	101.7/0.8	3.8/0.1	2.9/0.12	7.3/1.3	420/0.6	426.9/0.7	1.6/1.0
PK	123.2/0.8	7.7/0.7	1.0/0.6	143.7/0.9	131.8/0.8	3.8/0.2	3.1/0.3	78.3/0.7	302.9/0.8	323.9/0.8	8.8/1.1
Enrichment horizons											
PRG	58.0/0.6	3.0/0.6	0.4/0.6	60.6/0.5	54.8/0.2	4.0/0.1	3.2/0.1	2.9/0.5	260.6/0.5	263.5/0.4	1.1/1.0
SP*	58.0	3.5	0.5	52.3	30.6	3.5	2.9	2.9	260.6	263.6	1.1
PK*	30.4	2.9	0.4	92.9	59.1	4.2	3.6	2.4	137.8	140.2	1.7
Bedrock levels											
PRG	41.5/0.5	2.2/0.4	0.3/0.4	42.3/0.4	37.2/0.1	4.0/0.1	3.3/0.1	1.9/0.5	204.4/0.3	206.4/0.3	0.8/0.4
SP	24.3/0.4	1.8/0.4	0.2/0.6	63.8/0.5	34.4/0.3	4.2/0.1	3.7/0.1	1.2/0.4	129.9/0.3	131.1/0.3	0.9/0.2
PK	15.2/0.6	0.5/1.1	0.1/0.8	33.3/0.4	31.2/0.6	4.7/0.1	4.0/0.1	1.6/0.6	82.5/0.3	84.1/0.4	1.9/0.3

*No median or variation coefficients were computed due to there being only one level

zone and the mountain pine zone, the thickness of accumulative horizons was similar, i.e. 10 cm. The soils located in the mountain pine zone were characterised by the lowest average thickness of accumulative horizons – 7.8 cm.

On the basis of morphological features and the results of occurring pedogenic processes, the soils in the transects were classified to Hyperskeletal Leptosols (1 profile) and Skeletal Leptosols (1), Cambic Skeletal Leptosols (9 profiles) and Dystric Skeletal Leptosols (4 profiles) (Tab. 1) (Marcinek & Komisarek 2011).

Surface horizons of soils in the upper mountain zone under the acidophilic West Carpathian high mountain spruce (*PlagiothecioPicetum*) were characterised by higher contents of organic carbon, total nitrogen and sulphur, available phosphorus, and potassium, in comparison with analogous horizons in the soils of the transition zone and those formed under mountain pine shrubs. The lowest contents of these components were assessed in accumulative soil horizons of the transition zone (Tab. 2).

The concentrations of organic carbon, total nitrogen, sulphur, available phosphorus, and potassium in the enrichment horizons of the upper mountain zone soils were greatly diversified. In the soils of the other analysed altitude zones these horizons only formed in single profiles (Tab. 2).

Bedrock horizons in soils of the upper mountain zone were apparently more enriched in organic carbon, total nitrogen, sulphur, and available phosphorus in comparison with the analogous horizons of the transition zone and those developed under mountain pine. Unlike the accumulative horizons, the lowest concentrations of these elements in bedrock horizons were determined in the soils formed under mountain pine (Tab. 2).

The contents of the analysed elements assessed in the soils are comparable with the results obtained by other authors who conducted soil research on Babia Góra (Borowiec 1961; Adamczyk & Baran 1963; Adamczyk 1983; Miechówka et al. 1998, 2006; Niemyska-Łukaszuk et al. 1998a,b; Niemyska-Łukaszuk;

Kowalczyk & Miechówka 2001; Zadrożny & Miechówka 2008).

In all the soils, the contents of organic carbon, total nitrogen and sulphur, available phosphorus and potassium, decreased with their profile depth. The lowest concentrations of these elements were assessed in bedrock horizons (Tab. 2). Such an arrangement of the profile distribution of the analysed macro-elements resulted from a visible diversification between the surface accumulative horizons (with high contents of organic matter) and underlying sub-surface horizons. These results are seen in the high values of computed correlation coefficients r^2 between organic carbon content and concentrations of the other determined elements (C org. and N org. $r^2 = 0.8344$; C org and S org, $r^2 = 0.7575$; C org and K $r^2 = 0.7000$ and P $r^2 = 0.6224$).

In all the soils, the pH values assessed in the KCl solution did not exceed 4.5, which according to the division accepted in Poland (Gliński 1995), allows them to be classified as very strongly acid soils. The low pH in the soils results from their genesis from the bedrock which is a carbonateless Magura sandstone, and the characteristics of accumulated organic matter under plant communities occurring on them (Kowalczyk & Miechówka 2001; Miechówka et al. 2006; Zadrożny & Miechówka 2008).

On the basis of the assessed parameters determining sorption abilities, it was found that they characterise soils from the upper forest line (Tab. 2). In these soils, both in their accumulative horizons and bedrock assessed values of hydrolytic acidity and base exchange capacity, the sorption capacity and sorption complex saturation with exchangeable cations were higher than for the analogous soils of the transition zone and the mountain pine zone (Tab. 2).

In comparison with the subsurface horizons, high values of hydrolytic acidity assessed in the surface horizons of the analysed soils (irrespective of their location) resulted from the presence of acidifying compounds formed during biomass decomposition, with a considerable share of needles forming

the undergrowth (Kowalczyk & Miechówka 2001).

In all the soils, irrespective of the zone, the sorption complex of surface horizons was more saturated with base cations than in the subsurface horizons. The high content of base cations in the subsurface horizon of soils developed on carbonate-less substratum, may be evidence of their enrichment with metal dusts and other alkaline elements deposited in the upper parts of the Babia Góra massif (Grodzińska et al. 1990; Niemyska-Łukaszuk 1992; Niemyska-Łukaszuk et al. 1998b).

A characteristic feature of the analysed transects was the considerable changeability of the transects' chemical properties, both within individual profiles and individual altitude zones, favoured by the characteristic geological structure of the Babia Góra Mt (Alexandrowicz 2004), which to a considerable extent contributes to the development of a mosaic, greatly diversified soil cover within one soil profile. It can be seen, that soils whose properties are affected by diversified pedogenic processes – podsolization and browning, developed in a transect several dozen meters long, running from the upper forest line through the transition zone to the mountain pine zone.

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Conclusions

1. Soils of the analysed transects in the individual zones (upper forest line, transition, and mountain pine zone) differed by morphological and chemical properties and typological affiliation.
2. Differences occurring in soils from individual altitude zones are most probably the effect of slope processes occurring on these terrains and diversification of vegetation covering them, irrespective of their former pasturing use.
3. Diversification of soil properties within the profiles was greatly determined by the quantity and profile distribution of organic matter.

Acknowledgements

The work described here forms part of research project NN 306 070640 of the Polish National Science Centre, entitled *Natural and anthropogenic conditioning of the occurrence of the timberline on Babia Góra Mountain, and its dynamics over the last 200 years*.

Editors' note:

Unless otherwise stated, the sources of tables and figures are the authors' on the basis of their own research.

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